RESEARCH PAPER

Sustainable Development in Cotton Sector through Industrial Applications of Value Added Products from Cotton Stalk

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Abstract

Annually thirty million tonnes of cotton stalk is generated in India; most of which is treated as waste and burnt in fields leading to severe environmental pollution. ICAR-CIRCOT realised economic potential of value addition to cotton stalk and developed commercially viable and eco-friendly technologies for sustainable development in cotton sector. Cotton stalk supply chain model developed resulted in additional remuneration of Rs. 1500-2000/- per acre. Techno-economic feasibility of briquettes and pellets as renewable energy source resulted in establishment of around 50 briquetting and pelleting plants in Maharashtra as return on investment in briquetting and pelleting plant is 40% and 25% respectively. Utilization of pellets for cooking saves over 50% costs on LPG. ICAR - CIRCOT biomass based green crematorium found to be ecofriendly as it is good alternative to traditional wood based cremations and reduces deforestation and saves cost by 55%. Bio-enriched compost from cotton stalk has higher NPK which improves soil health and saves Rs. 9000/- per ha by replacing FYM. Oyster mushroom cultivation on cotton stalk showed that farmers can earn up to Rs. 6000/- per acre and that will help further improve nutritional security. These technologies helped to convert waste to wealth, generate renewable energy, improve soil health and protect environment. Entrepreneurship and employment opportunities are created for rural youths for supply of cotton stalk as a raw material for industrial applications, establishment of briquetting and pelleting industry, compost making, manufacturing of crematorium and cultivation of mushroom. These business models would contribute to increase income opportunities for farmers and entrepreneurs, especially in rural areas, and more overall in cotton sector. These business models based on commercially viable technologies need to be promoted for sustainable development in cotton sector.

Keywords : Cotton Stalk, Value Added Products, Industrial Applications, Business Models

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Introduction

Cotton is an important commercial crop of India and is the largest producer in the world with its production of 6.15 million tonnes in 2017-18 (ICAC, 2018). Cotton is grown in about 100 countries and traded in around 150 countries worldwide (Gurung *et al*., 2016). Cotton is cultivated mainly for its fibre which is the most important commercial product apart from the cottonseed and cotton stalks as its valuable by-products. Around 11 million tonnes of cottonseed and about 30 million tonnes of cotton stalk **(Fig.1)** is generated in India every year (Arude *et al*., 2018). Linter, hull and meal are the important by-products obtained after extracting oil from cottonseed which are used for preparation of value added products. In India very limited value addition is done to cotton stalk. Most of the cotton stalks produced are treated as waste, though about 5-6% being used for commercial purposes and around 15-20% is used as fuel by rural masses as domestic fuel **Fig. 2** and remaining bulk of cotton stalk is burnt off in the field **Fig. 3** leading to severe environmental pollution.

Fig. 1: Cotton Stalk

Fig. 2: Cotton stalk as domestic fuel

Fig. 3: Burning of cotton stalk in the field

Cotton stalk is comparable to the most common species of hardwood in respect of fibrous structure and chemical composition. Cotton stalk contains 60% holo cellulose, 27% lignin and 6% ash. The calorific value of cotton stalk is about 4000 kcal/kg (Arude *et al*., 2018). ICAR-Central institute for Research on Cotton Technology (CIRCOT), Mumbai, has done value addition to cotton stalk by developing techno-economically viable technologies and commercialized them. As cellulose and lignin content is more in cotton stalk, it can be used for making particle boards. The cotton stalk can be used for manufacture of briquettes and pellets as renewable source of energy and power generation as it has good calorific value. Cotton stalk can be converted to bio-enriched compost and can also be used for cultivation of edible mushroom.

Cotton by-products based industries are underdeveloped in India owing to several impediments, including, lack of logistics for supply of cotton stalk, lack of availability of equipment for uprooting and chipping, lack of awareness and information among the farmers about value added technologies, inadequate government policies to support the development of cotton by-product industries etc. The economic business opportunities can be realised by establishing cotton by-product based industries to move towards sustainable development and also to create entrepreneurship and generate employment in rural areas in cotton sector.

Cotton stalk supply chain model for industrial applications

Lack of viable logistic model for supply of chipped cotton stalks to the industries is a major reason for non- utilization of cotton stalks for industrial applications. Traditional method of uprooting cotton stalks with a traditional tool (*Chimta*) is very tedious and labour intensive process. Hence, it was not viable for supply of cotton stalks for any industrial uses. Therefore viable logistics model has been developed for supply of cotton stalks for pelleting, briquetting and power generation industries.

The viable supply chain model comprises of uprooting of cotton stalk by tractor operated V-type up-rooter, followed by sun drying, shredding by a tractor operated shredder **(Fig. 4)** and transportation of chipped cotton stalk with truck/tractor to briquetting and pelleting plant within the radius of 50 km. Chipped cotton stalk fetches price of Rs. 2500-3000 per tonne at factory gate. Additional remuneration of Rs. 1500-2000 per tonne to the cotton farmers, thus contributing to doubling famer's income (Arude *et al*., 2018). This cotton stalk supply chain model has been demonstrated to farmers and stakeholders, pelleting, and briquetting and power generation industry in Vidarbha region of Maharashtra. It resulted in creation of employment and entrepreneurship opportunities for rural youths in cotton growing regions. Around 50 briquetting and pelleting plants based on cotton stalks have been established in and around Nagpur.

Fig. 4: Cotton stalk shredder

Manufacturing of briquettes and pellets from cotton stalk for industrial applications

The calorific value of cotton stalk is about 4000 kcal/kg hence it can be used for manufacture of briquettes and pellets which can be used as a renewable source of energy. Briquetting and pelleting technologies are well developed and widely used commercially in developed countries. But lack of knowledge of technology and technical constraints were the causes for less adoption of this technology in India. To address these issues extensive research work was done to develop process protocol and value added products viz. briquettes and premium grade pellets from cotton stalk. Briquettes and pellets are prepared by densification at high temperature and pressure.

Briquettes **(Fig. 5)** find applications as an alternate fuel to coal and LPG in boilers in the sugar, paper, rubber, chemical and food processing industry. Briquettes also find application in power generation plant in place of coal. Besides this, briquettes can be used in forging, furnaces and brick kilns and for gasification. Cotton stalk briquettes can be used as an alternative to wood for burning dead bodies which would help reduce dependence on wood for cremation purpose. For establishment of briquetting plant with a capacity of 20 tonnes/day, an investment of Rs. 25 lakh is required for machinery. The return on investment in briquetting plant of capacity 20 tonnes/day is around 40% and payback period is around 2 years. Pellets **(Fig. 6)** are being used in cooking stoves as fuel for preparation of snacks and cooking of meals, especially in roadside dabhas, restaurants, etc. The utilization of pellets for cooking saves over 50% costs on fuel as compared to LPG gas price. Pelleting plant of capacity 3 tonnes/day can be established with an investment of Rs. 15 lakhs towards machinery. The return on investment for pelleting plant of 3 tonnes/day capacity is around 25% and payback period is around 3 years (Arude *et al*., 2018).

Fig. 5: Cotton stalk briquettes

Cotton farmers also get benefited by Rs. 1500-2000/- per tonne by selling of cotton stalks produced in their field. The utilization of cotton stalks based briquettes and pellets is a novel step towards doubling the farmers' income. The manufacturing of briquettes and pellets from cotton stalk biomass has created entrepreneurship opportunities for promotion of rural based industries and employment generation for rural youths in cotton growing region.

Continuous feeding pellet stove for burning of cotton stalk pellets

With the increase in commercial LPG prices and awareness about renewable energy, restaurants are switching over to pellet stoves, a cheap alternative for cooking. The commercially available pellet stoves allows burning of proprietary pellets having ash content ≤1%. Cotton stalk pellets having higher ash content in range of 6-8% are not being utilized in these stoves as it tends to choke ash collection system in the stove. Cotton stalk pellets have calorific value of about 4000 kcal/kg and can prove to be a good and inexpensive alternative to costly proprietary pellets. Hence ICAR-CIRCOT developed a Continuous Feeding Pellet Stove (CFPS) **(Fig. 7)** that can handle pellets having higher 6-8% ash content. The ashes formed during combustion process are deposited into the ash collection chamber where from it can be easily removed through ash collection doors while pellet stove is in operation. The pellet utilization capacity of ICAR-CIRCOT CFPS is 6-8 kg /h. CFPS for burning of cotton stalk pellets for commercial restaurants found to be economically viable as utilization of pellets for cooking saves over 50% costs on fuel as compared to LPG gas price. Entrepreneurs can start small scale industries for manufacturing of CFPS for cotton stalk pellets.

Fig. 6: Cotton stalk pellets

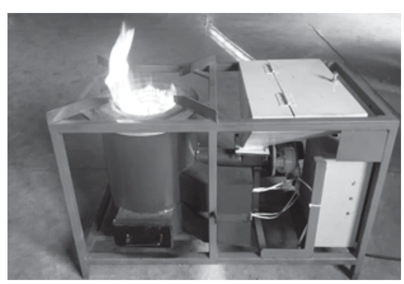

Fig. 7: ICAR-CIRCOT Continuous Feeding Pellet Stove

Cotton stalk biomass briquette based crematorium

ICAR-CIRCOT has developed briquette based green crematorium as an alternative to traditional fire wood based cremation. Briquettes made from agricultural biomass like cotton stalk can be used as greener and renewable alternative for fire wood in cremation. The ICAR-CIRCOT Green Crematorium **(Fig. 8)** consists of a compact trapezoidal shaped cage and a forced draft aeration system for supply of air for rapid initiation of fire and for enhanced combustion process. It requires only 200 kg of biomass briquettes as against 300 kg of fire wood in traditional cremations and does not require kerosene. Around 55% of cost saving per cremation can be attained making it economical and eco-friendly. Seventy five lakh cremations takes place annually in India. Saving of 300 kg fire wood per cremation would result in annual saving 150 lakh trees (Patil *et al*., 2019). Besides, use of biomass briquettes for cremation has tremendous potential for creation of rural based industries and employment generation.

Fig. 8: ICAR-CIRCOT Green Crematorium

Production of bio-enriched compost from cotton stalk and opportunities for farm entrepreneurship

Bio-enriched compost **(Fig. 9)** can be made out of cotton stalk using microbial consortia. An accelerated process has been developed by ICAR-CIRCOT for composting cotton stalk. Duration of composting is 45 days for wet and 60 days for dry cotton stalks. Yield of compost is 800 kg per tonne of cotton stalk. Accelerated process of composting saves 15 to 30 days of composting over farm yard manure (FYM). Bio-enriched compost made out of cotton stalks has higher NPK content (1.43:0.78:0.82) as compared to FYM (0.5:0.2:0.5). It results in saving of Rs. 9000 per ha by replacing FYM (12 tonne) with cotton stalk compost (5 tonne). It can be used for soil health enrichment as a substitute to chemical fertilizers (Mageshwaran *et al*., 2017). This technology is demonstrated through hands on training to farmers of Wardha, Nagpur and Amaravati District of Maharashtra and Sirsa of Haryana and many farmers have adopted it. Rural enterprises for production of compost from cotton stalk can be established at farm level in rural areas.

Fig. 9: Compost from cotton stalk

Developing cottage industry for cultivation of Oyster mushroom using cotton stalk

ICAR-CIRCOT has established the suitability of cotton stalks for production potential (growth performance and yield) of oyster mushrooms **(Fig. 10)** and developed the protocol for cultivation of oyster mushroom. Oyster mushroom (Pleurotus florida and Pleurotus ostreatus) can be cultivated on hot water treated cotton stalks of 3-4 cm length. The mushroom can be cultivated by hanging bag technique. About 300 g of fresh oyster mushroom could be harvested from one kg of dry cotton stalks. The cropping period for cultivation of oyster mushroom in cotton stalks is 30 days. An average of two harvests can be done per crop. The average cost of production of one kg of fresh oyster mushroom is Rs. 50/- The selling price of fresh oyster mushroom in the market ranges from Rs. 80 to 150/-. Thus, a farmer can earn a minimum of Rs. 30/- per kg of oyster mushroom produced. On an average, a famer can generate a minimum additional income of Rs. 6,000/- per acre by cultivation of oyster mushroom on cotton stalks generated from an acre of land (Satankar *et al*., 2018). Oyster mushroom cultivation using cotton stalk can be established as cottage industry in rural areas.

Fig. 10: Oyster mushroom cultivation on cotton stalk

Production of particle board, composites and activated carbon

ICAR-CIRCOT has developed technologies for preparation of particle boards **(Fig. 11),** composites **(Fig. 12)** and activated carbon from cotton stalk **(Fig. 13).** One tonne/day capacity pilot plant for preparation of particle boards from cotton stalks has been established at Ginning Training Centre of ICAR-CIRCOT, Nagpur with the financial assistance from Common Fund for Commodities (CFC), Netherlands. The quality of the particle boards from cotton stalk is comparable to that of particle boards made from wood.

These particle boards find applications in interior decoration, wall panelling, false ceiling, portioning, table tops, etc. Cotton stalk has cellulosic materials which is useful as reinforcement for polymer composites. Cotton stalk/epoxy composites have better mechanical and good thermal resistance properties and hence can be used in thermal resistance roofing panels in construction fields and automotive sector. The cotton stalk based activated carbon has higher micro-porosity and meso-porosity and surface area around 1000 m^2/g. It can be used for the various applications such as air filtration, water purification, medical application and dye adsorption from textile effluents. Face masks using activated carbon made form cotton stalk have been developed for the traffic police. Business models need to be established and promoted for production of particle boards and composites from cotton stalk.

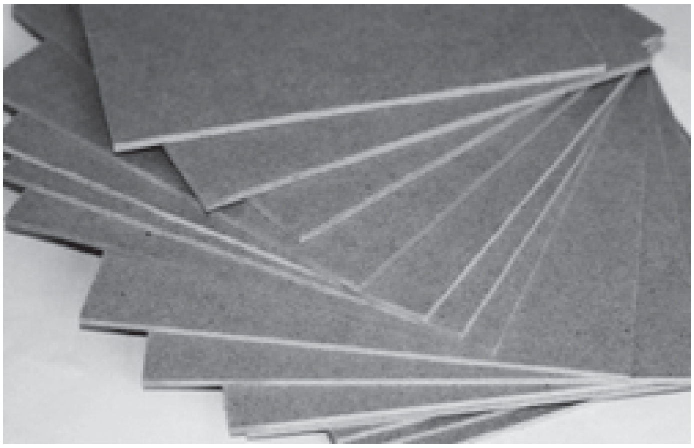

Fig. 11: Cotton stalk particle boards

Fig. 12: Cotton stalk composite trays for nursery

Fig. 13: Face masks of activated carbon from cotton stalk

Perspective of application of cotton stalk by-products in industrial applications

The biomass briquette and pellet industry has gained a rapid momentum over the past decade. The USA and most of European countries are the largest markets for biomass pellets. In Europe, pellets are mainly used for the production of electricity and residential heating. United Sates of America and Sweden procure about 4 and 13 % of their energy, respectively, from biomass and Sweden is implementing initiatives to phase out nuclear plants, reduce fossil-fuel energy utilization and enhance the use of bioenergy. Though, briquetting technologies are well developed and widely used commercially in developed countries, it is yet to receive a strong foothold in many developing countries because of the technical constraints involved and the lack of knowledge to adapt the technology to suit local conditions. Overcoming many operational problems associated with this technology are crucial factors in determining its commercial success. In India, the briquette and pellet industry is gaining momentum in last few years. Over 250 small and large size pelleting plants are being operational in India. The growing number of entrepreneurs in the state of Maharashtra in India, it is evident that biomass briquetting and pelleting industry has emerged as a promising option for the new entrepreneurs and other users of biomass in India. It requires low investment and can generate employment among the rural masses leading to improvement in social as well as economic life of rural people.

Conclusions

Techno-economically viable technologies developed and commercialized by ICAR-CIRCOT through value addition to cotton stalk by-produce. These ttechnologies helped to convert waste to wealth, generate renewable energy, improve soil health and protect environment. Entrepreneurship and employment opportunities are created for rural youths for supply of cotton stalk as a raw material for industrial application, establishment of briquetting and pelleting industry, compost making, manufacturing of crematorium and cultivation of mushroom. Successful business models based on technologies are demonstrated to stakeholders at national level and African countries. The utilization of cotton stalks and other agro-residues based briquettes and pellets is a step towards doubling the farmers income. Further this business model need to be strengthened so that more number of entrepreneurs will be benefitted. There is huge potential to establish profitable processing businesses in India based on cotton by-products, such as briquettes and pellets as successful business models exist in our country. This business models would contribute to increased income opportunities for farmers and entrepreneurs, especially in rural areas, and to a more extent in cotton sector. These business models based on commercially viable technologies need to be promoted for sustainable development of cotton sector.

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Cotton Facts: Breeding (ICAC, 2003)

Cotton is generally self-pollinating, but in the presence of suitable insect pollinators can exhibit some cross-pollination. Cotton is classified as an often cross-pollinated crop but for breeding purposes, it is treated as a self-pollinated crop, which is true for all cultivated species. Cotton, in spite of being an often cross- pollinated crop, does not suffer from in-breeding depression (loss due to self-pollination).

The extent of natural out-crossing in cotton depends on the climatic conditions where cotton is grown. The extent of natural cross-pollination varies even within a country. The cotton pollen grains cannot be carried by wind, and only insects carry pollen from one flower to another.

Genetics is a science of heredity. It is also a science of similarities and differences. This is a science that tells how traits are inherited and why an offspring is similar or different from the parents. Gregor Mendel published his work, *Experiments with Plant Hybrids*, in 1856. His work was so brilliant and unprecedented at the time it appeared that it took 34 years for the rest of the scientific community to catch up to it. Mendel's work was rediscovered in 1900 and the science of genetics was born.

Genetic mutations are the changes between or within chromosomes that may alter a phenotype, giving it greater or less advantage in the process of natural selection. Mutation brings a permanent change in the DNA sequence, which could have a minor or major phenotypic effect. Mutations in the reproductive cells are heritable and transmitted to the next generation. Mutations in the somatic (vegetative) cells are not heritable but may be transmitted once to daughter cells.